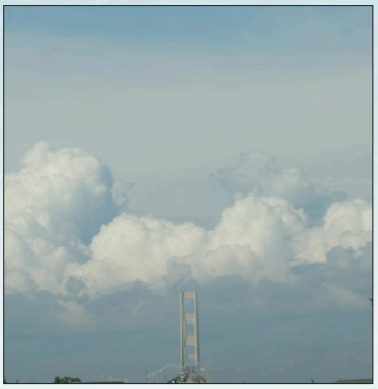
Regional Coupled Atmosphere-Lake-Land Modeling for Research and Applications



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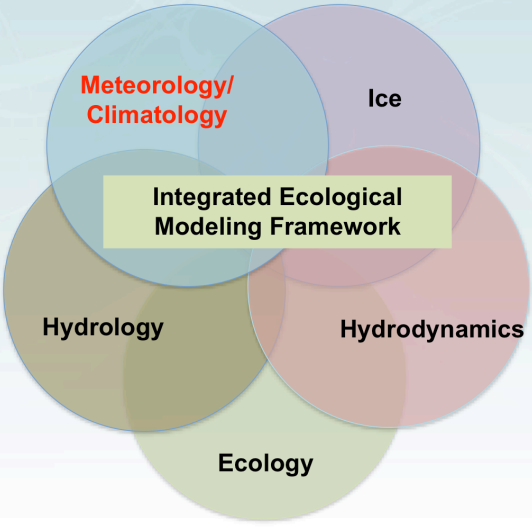
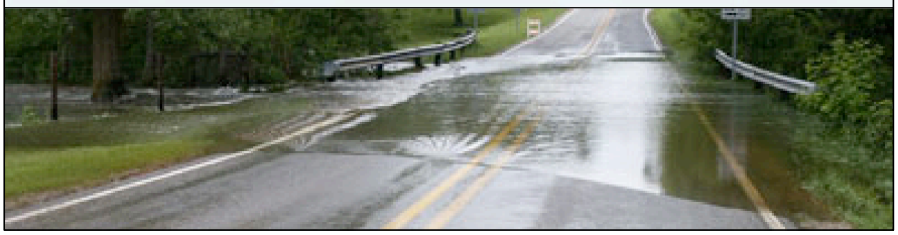
Using models to gain understanding of the regional atmosphere and its interactions and applying this knowledge



NOAA 5 Year Research Plan

Climate Mission Goal: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

- Document and understand changes in climate forcings and feedbacks, thereby reducing uncertainty in climate projections
- Improve skill of climate predictions and projections and increase range of applicability for management and policy

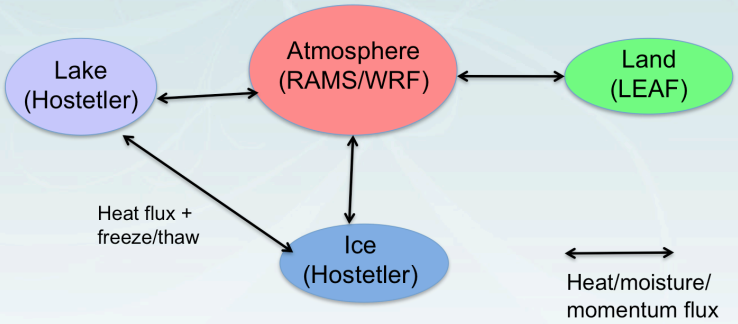


Questions

1) How does the system of atmosphere, land, and lake respond to increasing green house gas concentrations?
2) How does this influence the overall water budget of the basin?
3) How does that influence lake level?
4) What are the effects on lake temperature profiles and phenology?
5) Future direction: What are the ecological and socioeconomic impacts?

4. See Marjorie Perroud's poster in Ecosystem Modeling and Forecasting session.

Models for the Physical System



RAMS=Regional Atmospheric Modeling System

WRF=Weather Research and Forecasting Model

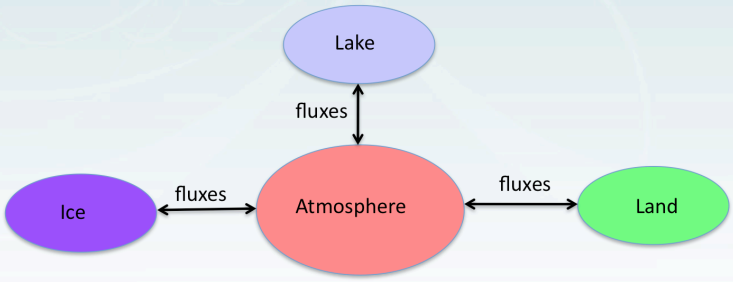
LEAF=Land Ecosystem Atmosphere Feedback

Who wants to know about this?

- International Joint Commission—water regulation
- New York Power Authority—hydropower
- Lake Carriers Association—navigation
- International Great Lakes Coalition for Shoreline Preservation, National Park Service—shoreline property and recreation
- USGS—fisheries impacts

Coupled Atmosphere-Surface Modeling

- The understanding that air temperature *causes* evapotranspiration has prevailed in the past
- Coupled atmosphere-surface modeling recognizes energy constraints and feedbacks



One of the primary examples of feedback that we concentrate on is that warming of the atmosphere-surface system can result in increased evapotranspiration (ET). However, this additional ET leads to cooling of the atmosphere-surface system, which inhibits the ET, i.e. a negative feedback. Ultimately, the more important governor of ET is the amount of heat energy that is coming into the system. In the past, air temperature has been used as a proxy for incoming energy in models that simulate only the surface system and use a prescribed atmosphere as a boundary condition. This ignores the energy budget that was presumed in the prescribed atmosphere used to force the surface model and ignores any negative feedbacks that are present either in that model or potentially in the real atmosphere.

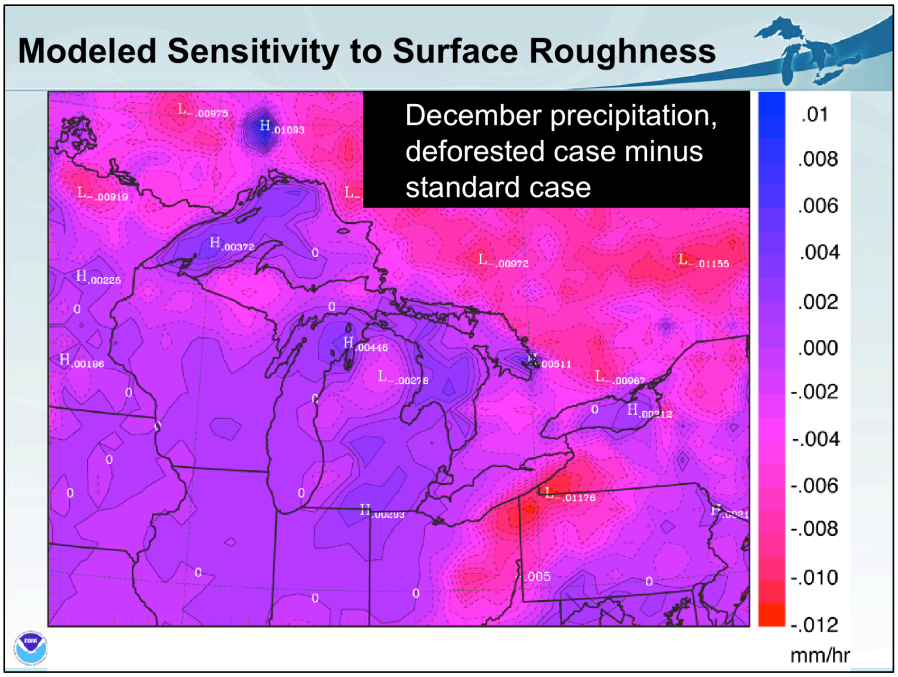
7

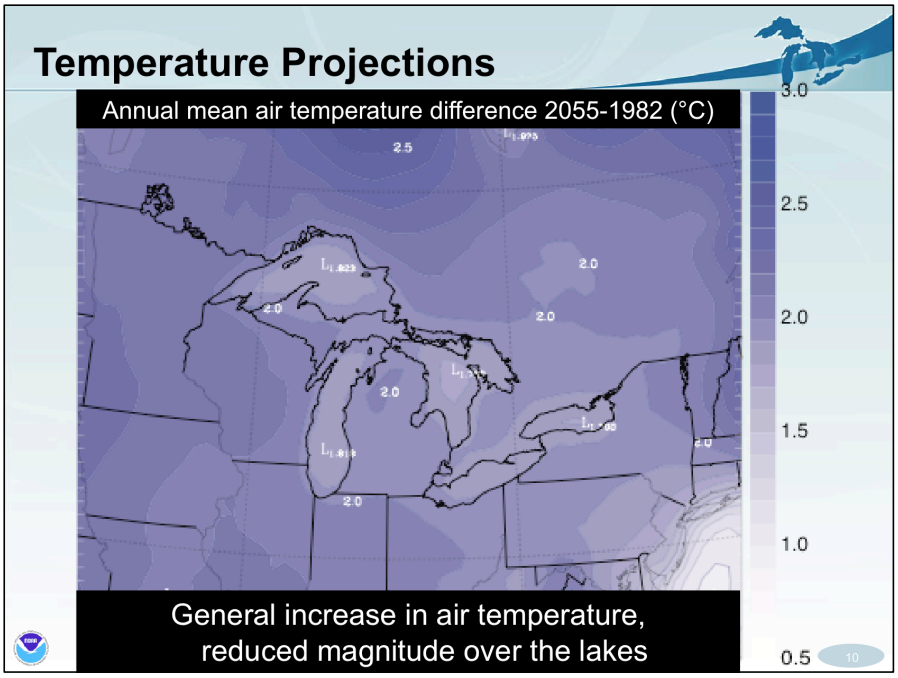
Two-Way Coupling

- Standard suite of atmospheric processes—equations of motion, radiation, diffusion, clouds, large-scale and convective precipitation
- Includes full coupling of lake and land surfaces with the atmosphere
- Complete interaction in their energy and water budgets

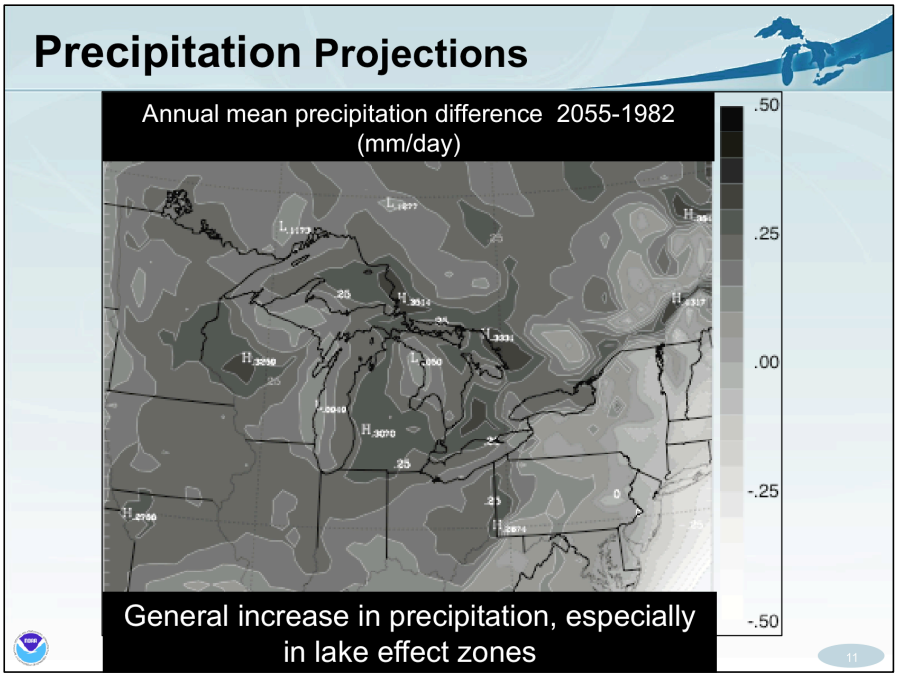
We have developed the Coupled Hydrosphere-Atmosphere Research Model (CHARM). This has the atmosphere interactive with the land surface and a simplified representation of the lakes. There are a large variety of outputs, including the basic atmospheric state variables of wind, temperature, humidity, pressure, and clouds, surface state variables such as lake and land surface temperature and soil moisture, plus surface-atmosphere interaction variables like incident and reflected sunlight, longwave radiative transfers, and fluxes of sensible and latent heat and momentum (friction). Each of these interaction variables represents an equal exchange of heat, moisture, and momentum between the atmosphere and the surface, and can mediate feedbacks between portions of the system.

8



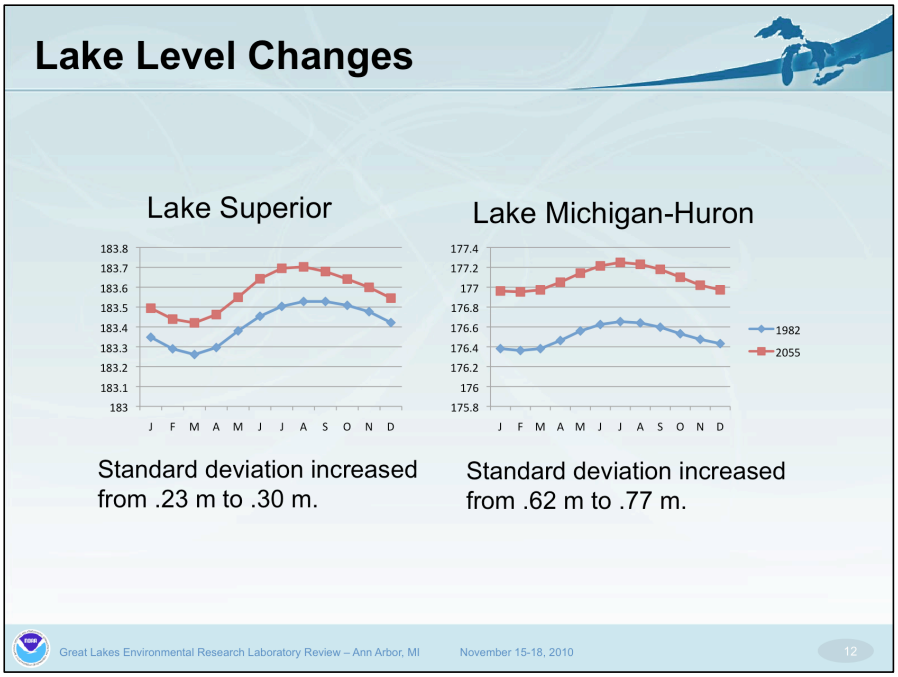


Two experimental cases of the CHARM model were run with greenhouse gas concentrations corresponding to a time period centered around 1982 and another centered around 2055.



Increased precipitation is a general prediction of models of climate change. This result shows a likelihood that increased precipitation will concentrate in specific places because of the presence of large lakes.

11



Net basin supply is the difference between precipitation and evapotranspiration over both the land and lake portions of the basin. Increased net basin supply is a precursor to the illustrated rises in lake levels.

These results represent the opinion of one model configuration, and in the future will be combined with other models to better gauge the associated uncertainty.

This work was completed as part of the International Joint Commission's Upper Great Lakes Study. The direct use in this study will be to better inform the policies used for regulating Lake Superior, i.e. how much water to allow to flow through the locks and compensating works in Sault Ste. Marie, Michigan-Ontario, connecting the outflow of Lake Superior to Lake Huron. The policies for this regulation are set through the International Joint Commission, a body representing the joint interests of the U.S. and Canadian governments in their shared waters, and they are implemented jointly by the U.S. Army Corps of Engineers and Environment Canada.

12

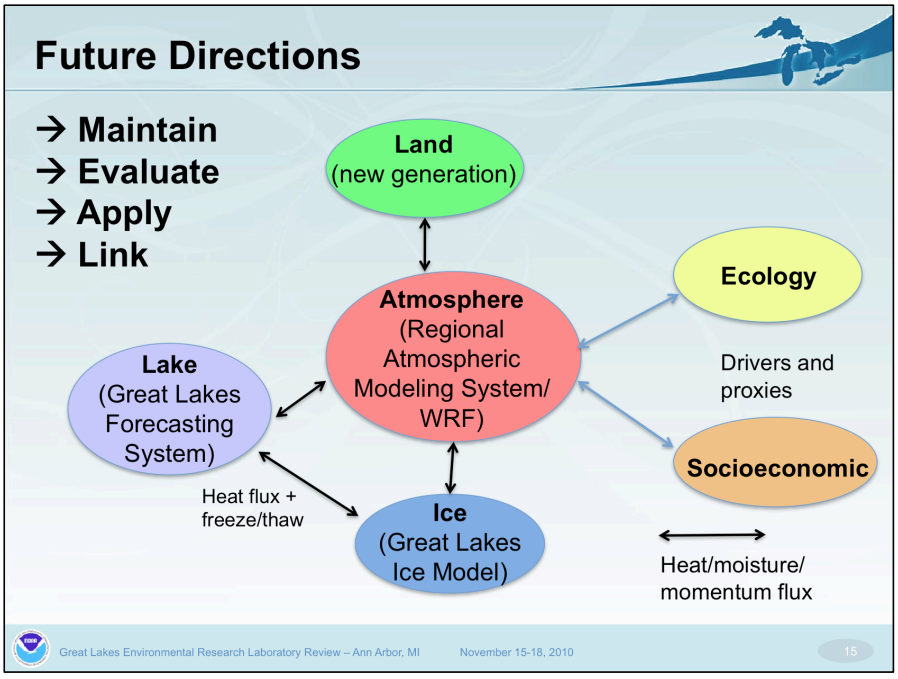
Resources

- This program requires the continuity that is enabled at a government lab.
- Computing: mostly remote (jet in Boulder), some shift anticipated to in-house

The computing burden of this work is heavy, and work has been hampered by this issue. However, our access to computing resources has improved through access to successive generations of ESRL's jet systems. We will soon have enhanced in-house capabilities using some multi-processor Macintosh systems. Integration of internal and external capabilities is enhanced by internet bandwidth.

Partners

- University of Wisconsin—similar regional climate modeling for comparison (EPA funded)
- Michigan Technological University—Kalamazoo River basin runoff and chemical loads
- US Geological Survey—study of lake temperature effects on fish
- International Joint Commission—net basin supply, lake levels, regulation plans
- Case Western Reserve University—hydrologic impacts
- NOAA Geophysical Fluid Dynamics Laboratory—global model input for regional model, fine-mesh global model

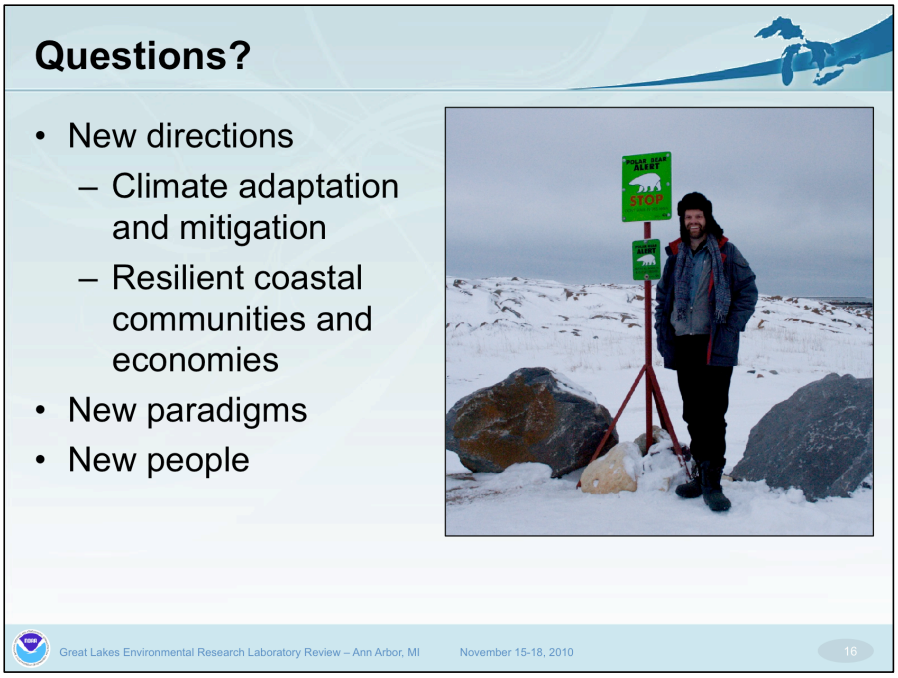


Mechanisms—e.g. climate change-lake interaction effects on continental-scale circulation, examination of GFDL's high-resolution GCM

Impacts—interfacing with impact research and jointly dealing with uncertainty

Coupling models for greater understanding of the larger system

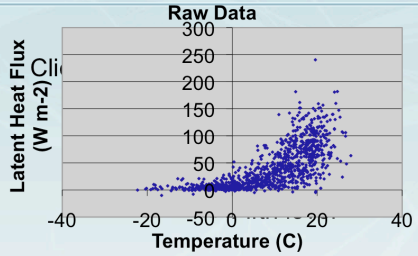
15

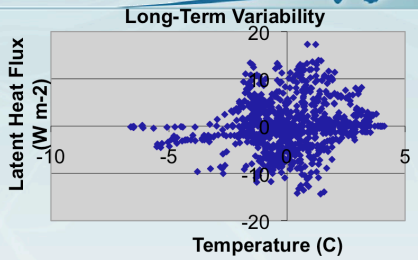


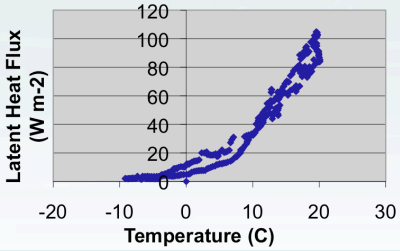
The new direction of **NOAA's next generation strategic plan** is heading towards emphases on climate adaptation and mitigation as well as increased focus on NOAA' s role in creating resilient coastal communities and economies.

16

Reserve Slides





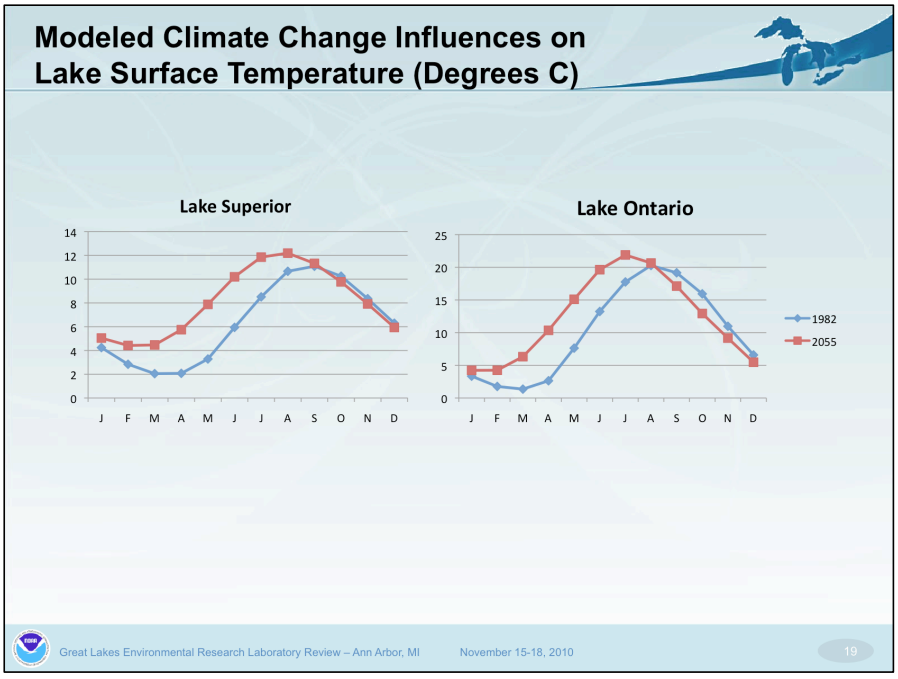


Former assessments of warming effects on lake levels assumed that air temperature *causes* evapotranspiration (ET), but:

Correlation only occurs for the annual cycle

Correlation is not causation

It is therefore incorrect to assume that the same relation exists between temperature changes due to greenhouse gases and ET as with changes due to the annual cycle



These results were quite surprising, and demand further investigation. In the simulation centered around 2055, the lake surface temperature is increased throughout most of the year relative to the simulation centered around 1982. However, during the fall, the temperature is the same or decreased. The reasons for this may include changes in mixing of the lakes, changes in clouds, or changes in wind.